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ABSTRACT

Endogenous Switching Costs and the Incentive for High Quality Entry

by Tomaso Duso*

This paper analyzes how the strategic use of switching costs by an incumbent influences entry, price competition and the entrant's incentive to introduce a high quality product, in a market with vertically differentiated goods. We can prove the existence of a unique subgame perfect equilibrium whose characteristics depends on the costs of developing quality. If these costs are low, the entrant strongly differentiates its product and price competition is tougher than without switching costs. If the costs of product's quality are in the middle range, the entrant differentiates its product less and each firm specializes on a group of customers. This implies a less competitive industry since both suppliers have market power over their purchasers. If the costs of differentiation are high enough, entry is deterred through the strategic use of switching costs. Furthermore we can show that the entrant always underinvests in quality when compared to the case of no switching costs. The equilibrium outcome is inefficient, since total welfare decreases in the presence of switching costs. Policy suggestions are discussed.

ZUSAMMENFASSUNG

Endogene Wechselkosten und die Anreize zum Markteintritt von Hochqualitätsproduzenten

In diesem Beitrag wird analysiert, wie ein „Incumbent“ durch die strategische Wahl von Wechselkosten - in einem Markt mit vertikal-differenzierten Gütern - den Eintritt, den Preiswettbewerb und die Qualitätswahl von potentiellen Wettbewerbern beeinflussen kann. Der Artikel zeigt die Existenz von einem eindeutigen teilspielperfekten Gleichgewicht, dessen Merkmale von den Qualitätskosten abhängen. Sind diese Kosten niedrig, so differenziert die eintretende Firma ihr Produkt stärker und der Preiswettbewerb ist intensiver als ohne Wechselkosten. Wenn die Qualitätskosten in einem mittleren Bereich liegen, differenziert die eintretende Firma ihr Produkt weniger und die Firmen spezialisieren sich auf unterschiedliche Konsumentengruppen. Dies reduziert die Wettbewerbsintensität, da beide Produzenten Marktmacht über ihre jeweiligen Kunden besitzen. Wenn die Differenzierungskosten hoch genug sind, wird der Eintritt durch die strategische Nutzung von Wechselkosten verhindert. Außerdem zeigt der Artikel, daß die eintretende Firma im Gleichgewicht immer weniger in Qualität investiert als ohne Wechselkosten. Das Gleichgewicht ist ineffizient, weil die Wohlfahrt mit Wechselkosten abnimmt. Wirtschaftspolitische Implikationen werden diskutiert.

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1 Introduction

> *"The [European] Community's aim is to support the competitiveness of the European economy in an increasingly competitive world and to give consumers more choice, better quality, and lower prices [...]"*[1].

In the process of opening up some industries to competition the ex monopolistic firm has some advantages *vis-à-vis* potential entrants. In particular, if the incumbent's consolidate base of customers perceive switching to a new seller as costly, then the incumbent has market power over its potential repeat-purchasers. The general trade off that the incumbent faces in markets with switching costs is between setting high prices in the monopoly period, in order to extract the maximal rent in that period, and setting low prices in order to lock in consumers for the future. If customers are locked in, the ex-monopolist can charge them with higher prices in the competitive period, increasing its expected profits. Furthermore, if the monopolist can endogenously create switching costs, their strategic use may help to deter new entry or to maintain a dominant position in the market, and thereby harm competition.[2] One further interesting point, which seems so far not to be thoroughly analyzed by the literature, is how do switching costs influence the competitors' incentive to differentiate its product, and which implications has this fact on industry's competitiveness and total welfare. The question is whether switching costs give incentives to a potential entrant to play more aggressively in the quality dimension. The entrant would in this case strongly differentiate its product in order to respond to the incumbent's strategic use of switching costs, and to improve its position in the market. But that may have negative implications for the industry's overall competitiveness. On the other side, because of switching costs, the entrant could have the incentive to differentiate its product less in order to keep the incumbent unaggressive in a sort of "collusive" outcome. However less differentiation could also imply a more competitive industry, because firms could compete harder in the price

[1] European Union Commission, 'Services of General Interest in Europe', 96/C/281/03, OJ 281, 26 September 1996.

[2] There are several examples of the strategic use of switching costs by an incumbent. One of these is the behavior of Deutsche Telekom AG, the ex-monopolist in the German fixed telephone industry. April 1998, as this industry was opening up to competition, the incumbent presented a request to the German authority for Post and Telecommunications, where it proposed to charge 46 DM to those of its customers who wanted to permanently change their telecommunications service provider *via* preselection. The competition authority did not accept this request. It decided on a decreasing price plan which, as of 1^{st} January 2000, charges 10 DM as a cost-covering conversion rate.

dimension. This paper aims to study more deeply this issue: the interaction between switching costs and the product's quality. In addition, we are interested in analyzing how these two strategic variables influence the entry process and product market competition.

We present a dynamic model of price competition with product differentiation. Consumers are heterogeneous because they are assumed to have different tastes for quality. We consider that the industry under study is liberalized. The first mover is the entrant who invests, by assumption, in a high quality product. The choice of the degree of vertical product differentiation depends on the "costs of quality" or "costs of differentiation", which are assumed to be exogenous and known. Depending on the entrant's quality choice, the monopolist can try to lock in consumers through the strategic use of switching costs and its pricing behavior before the second firm enters the market.[3] Finally, after entry has occurred, firms compete in the price dimension.

There exists much literature which has analyzed the role of switching costs. A pioneering work is the paper by VON WEIZSÄCKER [1984]. He studied the interaction between the *exogenous* "cost of substitution" (i.e. switching costs) and *horizontal* product differentiation. The main result is that, if consumers are uncertain about their future preferences, the degree of product differentiation declines and industry competitiveness increases as switching costs rise.[4] Even though no welfare analysis is attempted, the conclusions suggest that switching costs may not be an impediment to competition, as thought to be.

The role of consumers' *exogenous* switching costs has also been intensively studied by KLEMPERER [1987a, 1987b].[5] As he pointed out "[t]he most obvious effect of switching costs is to give firms some market power over their existing customers, and thus to create the potential for monopoly profits". This effect may have different implications. The existence of exogenous switching costs can explain some pricing behavior as price wars (low price in the first period to lock in customers followed by high price in the second period to extract monopoly rent), but can also explain entry deterrence.[6] Furthermore KLEMPERER [1988] has shown that, when there are

[3]These are probably our main simplifying assumptions: we analyze only the case of a *high quality* entrant, and we do not allow the incumbent to respond strategically in the quality dimension.

[4]The author assumes that consumers may in the future change their "location" according to a stochastic process.

[5]For a overview of the role of switching costs and the application to different economic fields, see also KLEMPERER [1995].

[6]A generalization of this kind of model to a fully dynamic setting is offered by FAR-

exogenous switching costs and products are not differentiated, the entry of efficient low-cost firms can be socially detrimental because competition among firms is tougher and therefore firms' profits decrease.[7]

The paper that we think to be closest to the spirit of our model is AGHION and BOLTON [1987]. In contrast to our setting, their model assumes homogeneous products and homogeneous consumers, but on the other side it also introduces uncertainty about entrant's costs, which is not analyzed in our setting. They have shown that long term contracts, which contain liquidated damages clauses (i.e. *endogenous* switching costs), can be used by a seller as a barrier to entry, leading to an inefficient and anti-competitive industry. An entrant comes into the market only if it is more cost-efficient than the incumbent, but, in the presence of exclusive dealing contracts between buyer and seller, it enters with a smaller probability than in the social optimum case.

Also, the model presented in this paper can be related to the literature on entry and vertical product differentiation. To this regard, however, one should keep in mind that generally this literature analyzes the case in which both firms compete in the quality dimension.[8] We will instead consider the case where only the entrant can use strategically its quality choice, while we concentrate on switching costs as the incumbent's main strategic variable.

In the literature, thus, there are still some open questions to answer. The paper by von Weizsäcker suggests that exogenous switching costs may reduce product differentiation and in this sense may not have anticompetitive effects, since less differentiation implies that firms compete harder in the price dimension. On the other side Klemperer and Aghion and Bolton come to the conclusion that both exogenous and endogenous switching costs may generate inefficiency, but they do not consider product differentiation. Our contribution tries to consider both issues (endogenous switching costs and vertical product differentiation) simultaneously.[9]

RELL and SHAPIRO [1988]. In their overlapping-generations model they have shown that, if economies of scale (or network externalities) are moderate, the incumbent tends to exploit its existing buyers and to compete less hardly for the new customers. There is then too much (inefficient) entry.

[7] In his model consumers' surplus is, instead, always increased by new entry, but this positive effect may be dominated by the negative effect on profits.

[8] See for instance LUTZ [1997]. He has shown, with a model very similar to the one we have adopted, that the ability of an incumbent to deter entry through the strategic use of its product's quality crucially depends on fixed costs, quality dependent costs and market size. The main reference for a model of vertical product differentiation is by SHAKED and SUTTON [1982].

[9] Another related paper is by CARMINAL and MATUTES [1990]. They analyze a duopoly setting with horizontal product differentiation and endogenize switching costs,

With respect to the works by von Weizsäcker and Klemperer our model will analyze *endogenous* (contrast to exogenous) switching costs. Furthermore we also introduce vertical product differentiation, which was not studied in Klemperer's papers, whereas von Weizsäcker analyzed horizontal product differentiation. Our paper can also be seen as a sort of generalization of Aghion's and Bolton's model with respect to the assumptions on consumers' heterogeneity and product differentiation.

Our main result is that the deliberate use of switching costs by the incumbent reduces the degree of product differentiation with respect to the no switching costs case. This finding is similar to VON WEIZSÄCKER's [1984] result, even though the forces leading to it are very different as well as the implications for industry's competitiveness. In our case, in fact, it is the incumbent's strategy to reduce the entrant's incentive to differentiate and not exogenous factors in the market. We shall further show that, depending on the entrant's investment costs of developing quality, different equilibrium outcomes may emerge. In particular, if these costs are very low, the entrant strongly differentiates its product and both firms set prices very aggressively, even more so than without switching costs. When the costs of differentiation are in the middle range, we observe less product differentiation and a looser competition: both firms specialize on a group of consumers and extract a monopoly rent from them. This finding differs from standard results of the literature on vertical product differentiation since in our model higher entrant's quality implies an higher degree of competition. Finally, for high investments costs entry is deterred by the strategic use of switching costs. This suggests that AGHION's and BOLTON's [1987] result holds true also when one introduces product differentiation. Furthermore, we can also show that total welfare is always decreased by switching costs, even in the case in which they enhance industry's competitiveness. This last finding seems to be in line with KLEMPERER [1988].

The model is described in Section 2. In Section 3 we present the solution of the price setting game: first we analyze the benchmark case of no switching costs, then we present two candidate equilibria, and finally we discuss the equilibrium outcome of the price setting game and make some comparative static analysis with respect to entrant's quality. In Section 4 we present the entrant's quality choice, and finally analyze welfare implications which enables us to present some policy suggestions. Section 5 concludes the paper with some remarks.

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which they do by considering two alternative firms' strategies: price precommitment and the use of coupons. Depending on the kind of model adopted they find that switching cots may increase or decrease industry competitiveness and welfare.

2 The Model

The model is formalized as a three stage game. The players are an incumbent (I), an entrant (E), and consumers (t).

We assume that at a given point in time the industry under consideration, which is served by a monopolist, is opened to competition.[10] The monopolist's competitive advantage is to have already invested in the quality level $\overline{q}_I = 1$, and thus it does not face sunk investment costs during the game.[11] The entrant, instead, has to make a new investment in technology. Since it comes later into the market, it can enjoy by assumption a more developed technological environment, which allows it to set up a higher product quality than the incumbent. Thus, the entrant is in our model the high quality provider.[12] We assume for simplicity that the entrant's decision is made at the very beginning of the game (in period 0). A motivation for this timing can be that investment's decisions need some time to be implemented. If the entrant chooses to invest in quality, this means that it will enter the market in period 2. The costs to set up the desired quality level are convex and represented by the following function:

$$c_E\left(q_E\right) = c \cdot \frac{q_E}{\left(2 - q_E\right)}, \tag{1}$$

where c is a cost parameter. This cost function implies that the costs for quality are positive for $q_E > 0$ and increase to infinity with q_E going to 2. An economic interpretation is that entrant's innovation is not *drastic*, i.e. the entrant's product quality can not be so high that the incumbent's product is crowded out completely.[13]

In the first period the incumbent offers a contract where, given its exogenous quality level ($\overline{q}_I = 1$), it determines its first period price p_I and the level of switching costs s.[14] Consumers choose whether they want to buy in this period. They know that by signing the incumbent's contract they forgo some benefits of potential entry, because of the possible lock in effect that

[10] That is what happened in many network industries in the last years. For the case of Europe see for instance BERGMAN and AL. [1998].

[11] Incumbent's quality is then exogenous and normalized to 1.

[12] Analytically this assumption implies $q_E > \overline{q}_I = 1$.

[13] See AGHION and HOWITT [1992] for a discussion on *drastic* innovation. Even though it is a strong simplifying assumption, we do not think that it could change the main results of the model. We expect, in fact, that relaxing this assumption the main difference would be the possible existence of further equilibria.

[14] Switching costs are determined in the first period contract, but they are payed only in the second period by those incumbent's attached costumers who want to change firm affiliation.

switching costs imply.

At the beginning of the second period the entrant offers a contract where its product's quality level (q_E) and its price (p_E) are determined. Simultaneously the incumbent also offers a contract where a second period price ($p_{I,2}$) is specified.[15] After having observed the contracts, consumers decide whether they want to stay by the incumbent, whether they want to switch to the entrant, or whether they want to begin to buy (in case they did not consume earlier) either from the entrant or from the incumbent. Later on in the paper we will refer to the first period purchasers as "attached" customers and to the consumers who buy only in the second period as the "new" customers.

There is a continuum of heterogeneous consumers characterized by a taste (income) parameter t, which is distributed uniformly over the interval $[0, 1]$. The higher this parameter is, the more consumer t likes quality. The per period utility function of consumer t takes a simple linear form and is given by:

$$u^t = tq_j - p_j, \tag{2}$$

where $j = I, E$. Consumers' outside option guarantees a utility level of zero.

3 Solution of the Price Setting Game

We look for the subgame perfect equilibrium in pure strategy. We then solve the game by backward induction starting from the second period. All agents are perfectly rational and there is complete but imperfect information.[16]

To determine demand in the second period, we need to know who are the locked in consumers in order to solve the model backward. In the first period the consumers' decision is limited to a binary choice: they can buy one good from the incumbent or not buy at all. We assume that consumers are rational, this implies that in the first stage they decide taking into account not only their utility in that period but also their utility in the next one. In particular they consider that to buy today means to be possibly locked in by the incumbent in the future. We denote utility in the first period as u^t_y, where $y = 0, I$, and utility in the second period as $u^t_{y,x}$, where $x = 0, I, E$.

[15] Note that, although we do not allow the incumbent to discriminate between attached costumers and new consumers, switching costs act actually as a discriminatory device. See BESTER and PETRAKIS [1996].

[16] This is because firms price simultaneously in the second period.

Consumers then compare in the first period the sum of the utilities they get under the different options: $u_y^t + u_{y,x}^t$.[17]

Remark *In the first stage there exists a unique "cut-off" consumer (t_0) who is indifferent with respect to buy or not to buy, for every value of the second period prices.*

This result is similar to the so called *single crossing condition* in the signalling literature.[18] It stems from the assumptions that agents' preferences are monotonically increasing in t, and that the slope of the preference curves of higher types (i.e. types who buy high quality) is bigger than those of worse types since $q_E > \overline{q}_I = 1$. All consumers with a type higher than t_0 buy and all those with type lower than t_0 do not buy. Thus, in the second period $(1 - t_0)$ consumers have already bought, and must pay s if they want to change firm affiliation. In the literature this is called the *locked in* effect. Their second period utility is therefore given by:

$$u_{I,x}^t = \begin{cases} 0 & & x = 0 \\ t - p_{I,2} & \text{if} & x = I \\ tq_E - p_E - s & & x = E \end{cases} .$$

Also, there are t_0 consumers who decided in the first period not to buy. For them the second period utility function can assume the following values:

$$u_{0,x}^t = \begin{cases} 0 & & x = 0 \\ t - p_{I,2} & \text{if} & x = I \\ tq_E - p_E & & x = E \end{cases} .$$

Depending on prices, switching costs, and entrant's quality we can now define some second period cut-off customers t_i by comparing utility levels by pairs. In Table 1 we report the position of the indifferent consumers. For example, reading the first line of Table 1, all consumers with a type lower than t_1 bought in the first period and in the second period they decide to buy from the incumbent (getting $u_{I,I}^t$), and all types higher than t_1 bought in the first period and in the second period switch to the entrant (getting $u_{I,E}^t$).

[17] Note that, for simplicity, we do not introduce a discount factor. Our specification implicitly assumes that it is equal to 1, and this means that consumers are very patient.

[18] See for instance FUDENBERG and TIROLE [1991] pg. 259.

Table 1. Second Period Indifference Values		
Second Period Utility Comparison	Second Period Cut-off Consumers	Comparison
$u_{I,E}^t = u_{I,I}^t$	$t_1 = \frac{p_E - p_{I,2} + s}{q_E - 1}$	$t > t_1 \Longrightarrow u_{I,E}^t > u_{I,I}^t$
$u_{I,I}^t = u_{0,I}^t = 0$	$t_2 = p_{I,2}$	$t > t_2 \Longrightarrow u_{I,I}^t = u_{0,I}^t > 0$
$u_{I,E}^t = 0$	$t_3 = \frac{p_E + s}{q_E}$	$t > t_3 \Longrightarrow u_{I,E}^t > 0$
$u_{0,E}^t = u_{0,I}^t$	$t_4 = \frac{p_E - p_{I,2}}{q_E - 1}$	$t > t_4 \Longrightarrow u_{0,E}^t > u_{0,I}^t$
$u_{0,E}^t = 0$	$t_5 = \frac{p_E}{q_E}$	$t > t_5 \Longrightarrow u_{0,E}^t > 0$

The cut-off consumers' position, i.e. the relation between the t_i's, determines the demand for either firms.[19] Depending on the actual choice of quality (which depends on the cost parameter) that determines the choice of the switching costs level and of prices, several different demand configurations are possible.[20] In what follows we will pick out two possible demand configurations, our "candidate equilibria". Then, in Proposition 1, we will show that they are part of the equilibrium outcome of the price setting game, where the choice of the equilibrium depends on the quality choice and thus on the actual cost of producing quality.

We give a notation for the demand functions. In the first period $D_I(\cdot) = (1 - t_0(\cdot))$ consumers buy from the incumbent. In the second period the incumbent attracts $D_{I,I}(\cdot)$ of its attached customers, and $D_{0,I}(\cdot)$ of the t_0 consumers who didn't buy in the previous period. The entrant serves $D_{I,E}(\cdot)$ of the consumers who bought in the first period, and $D_{0,E}(\cdot)$ of those who waited.

We further assume that both firms have zero marginal costs of production. We can now write firms' payoffs in a general form as follows:

$$\pi_I(q_E, p_I, s, p_{I,2}, p_E) = p_I D_I(\cdot) + p_{I,2}\left[D_{I,I}(\cdot) + D_{0,I}(\cdot)\right] + s D_{I,E}(\cdot), \quad (3)$$

and

$$\pi_E(q_E, p_I, s, p_{I,2}, p_E) = p_E\left[D_{I,E}(\cdot) + D_{0,E}(\cdot)\right] - c_E(q_E). \quad (4)$$

All consumers who switch must pay the incumbent a switching cost s, and for this reason $D_{I,E}(\cdot)$ appears in the incumbent's profit function.

[19] The position of the indifferent consumers results in some restrictions on the strategic variables. These restrictions must be satisfied in equilibrium, in which case we are allowed to say that those particular demands exist, and lead to an equilibrium outcome.

[20] We present all the possible demand configurations in Appendix 1.

3.1 The Benchmark Case

The benchmark case we consider is that of no switching costs.[21] If there are no switching costs, the solution of the model becomes much simpler than in the general case, because consumers cannot be locked in by the incumbent and therefore the two periods are not strategically linked. In the second period the only possible demand configuration is $D_{y,I}(\cdot) = (t_4 - t_2)$ and $D_{y,E}(\cdot) = (1 - t_4)$ for every $y = 0, I$.

Note that in this case it is not relevant what happened in the previous stage and second period prices depends only upon the entrant's quality. Solving the maximization problems we obtain:

$$\widehat{p}_{I,2} = \frac{q_E - 1}{4q_E - 1}, \tag{5}$$

$$\widehat{p}_E = \frac{2q_E(q_E - 1)}{4q_E - 1}. \tag{6}$$

Since there aren't switching costs, in the first period consumers take their decision independently of what will happen in the second. The value of t_0 is then equal to p_I.[22] The incumbent faces a first period demand $D_I(\cdot) = (1 - t_0)$. The solution is the standard monopoly solution:

$$\widehat{p}_I = \frac{1}{2}. \tag{7}$$

Figure 1 shows the second period utility levels and demand for the benchmark case when $q_E = 1.5$.[23] Half of the consumers buy in the first period.[24] In the second period all these consumers switch to the entrant. Some of the consumers who waited in the first period buy in the second from the entrant, some from the incumbent, and the very low type don't buy at all in either

[21] It is worth noting that this may be a second best solution, which is the most reasonable in terms of implementable competition policy. We think that the most interesting analysis is to compare market performance in the case of switching costs *versus* the case of no switching costs. Looking for the first best would mean to find the level of switching costs which maximizes total welfare and which may even imply a subsidy to switch.

[22] In fact $u_I = 0$ implies $t_0 = p_I$.

[23] Note that the figure entails the equilibrium prices for the given quality level and that the assumed quality level is *not* the optimal quality level, which will be later derived endogenously as a function of the quality cost parameter c. To draw the picture we picked up one possible quality level.

[24] Note that this is a general property, since the number of consumers who buy in the first period $(1 - t_0)$ does not depend on q_E. This is because $t_0 = p_I = 1/2$ for every $q_E \in (1, 2)$.

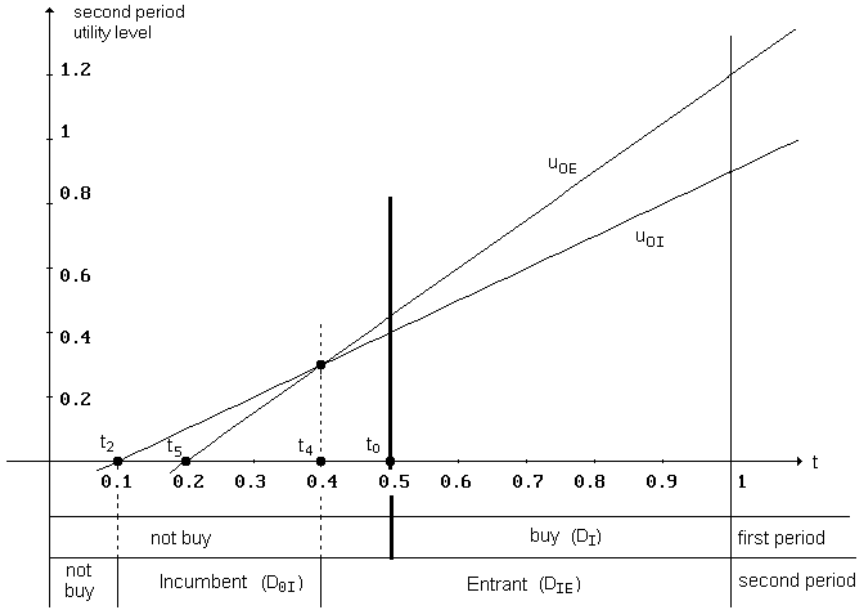

Figure 1: The benchmark case: Demand ($q_E = 1.5$).

period. In the benchmark case *all* the high type consumers, i.e. those who have a high t, switch to the high quality provider.

3.2 First Candidate Equilibrium

We can now present our first candidate equilibrium. In what follows we will concentrate on one particular demand configuration (Case 1 in Appendix 1) which exists under particular restrictions on the set of prices, determined by the position of the indifferent consumers.

If the cut off consumers are positioned as follows: $1 \geqslant t_1 > t_0 > t_4 > t_2 \geqslant 0$, then the resulting demand configuration is: $D_I(\cdot) = (1 - t_0)$, $D_{0,I}(\cdot) = (t_4 - t_2)$, $D_{I,I}(\cdot) = (t_1 - t_0)$, $D_{0,E} = (t_0 - t_4)$, $D_{I,E}(\cdot) = (1 - t_1)$. We will now solve the game given this demand and check at the end whether the equilibrium outcome we will derive is such that the indifferent consumers can actually be positioned as we assumed.

In the second stage the incumbent maximizes its profit with respect to $p_{I,2}$, and the entrant maximizes its profit with respect to p_E. Solving the first order conditions together, we obtain the optimal second period prices as a function of t_0, s, and q_E. Note that t_0 is a function of s, p_I, and q_E as well, but in the second period is taken as given. We can write then the optimal second period prices for this demand configuration as:

$$\widetilde{p}_{I,2} = \frac{(q_E - 1)(t_0 - 1) - s}{2(2q_E + 1)}, \tag{8}$$

$$\widetilde{p}_E = \frac{q_E^2 (t_0 + 1) - q_E(s + t_0) - 1}{2(2q_E + 1)}. \tag{9}$$

Incumbent's second period price decreases with the number of consumers who don't buy in the first period (t_0), whereas entrant's price increases in t_0 as one would expect.[25] In fact for every $q_E \in (1, 2)$ we obtain:

$$\frac{\partial \widetilde{p}_{I,2}}{\partial t_0} = \frac{1 - q_E}{2(2q_E + 1)} < 0 \quad \text{and} \quad \frac{\partial \widetilde{p}_E}{\partial t_0} = \frac{q_E(q_E - 1)}{2(2q_E + 1)} > 0 \ .$$

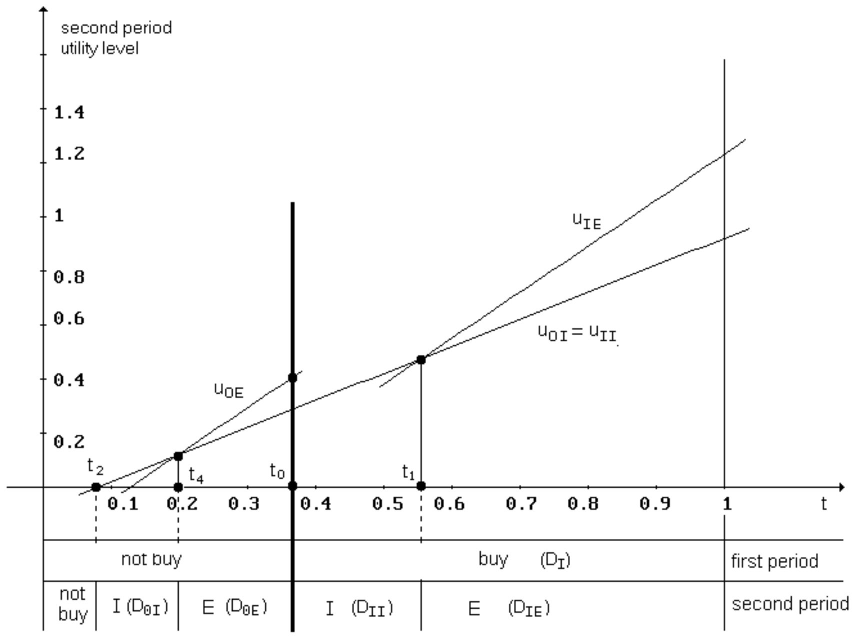

Figure 2: First candidate equilibrium: Demand ($q_E = 1.7$).

[25]This reflects incumbent's strategic incentive given by the lock in effect. If few consumers are locked in, in fact, the incumbent must set the second period's price more aggressively to compete for the "new" costumers.

Before solving the first period we must determine t_0 as a function of the first period decision variables. Looking at Figure 2 one can see that, under the condition we assumed, the cut-off consumer who is indifferent between buying or not in the first period makes its choice knowing that if it does not buy, it will buy from the entrant in the next period, and if it buys, it will be locked in by the incumbent in period 2.[26] it compares than $u_0^{t_0}+u_{0,E}^{t_0}$ and $u_I^{t_0}+u_{I,I}^{t_0}$ to take its first stage decision. We obtain then $t_0 = (p_I + p_{I,2} - p_E) / (2 - q_E)$. As expected the number of consumers who do not buy in the first period (t_0) increases with increasing first and second period incumbent prices, while decreases with an increasing entrant's price. Substituting (8) and (9) in the utility functions we can solve for $\widetilde{t}_0$:

$$\widetilde{t}_0 = -\frac{2p_I (2q_E + 1) - q_E^2 + q_E (s+1) + s}{3 (q_E^2 - 2q_E - 1)}. \tag{10}$$

In this candidate equilibrium the number of consumers who wait in the first period increases both in p_I and in s. Consumers are less willing to buy in the first period if the incumbent's product is very expensive, or if they know that the cost for switching in the next period is very high. In fact for every $q_E \in (1,2)$ it holds:

$$\frac{\partial \widetilde{t}_0}{\partial p_I} = -\frac{2(2q_E+1)}{3\left(q_E^2-2q_E-1\right)}, \quad \text{and} \quad \frac{\partial \widetilde{t}_0}{\partial s} = -\frac{q_E+1}{3\left(q_E^2-2q_E-1\right)} > 0 > 0.$$

Now we can substitute (8), (9), and (10) in the incumbent's profit function and solve the first period maximization problem. In the first period the incumbent chooses p_I and s:

$$\widetilde{p}_I = -\frac{q_E^2 - 2q_E - 1}{3q_E + 1}, \tag{11}$$

$$\widetilde{s} = \frac{(q_E - 1)(2q_E + 1)}{2(3q_E + 1)}, \tag{12}$$

and substituting in (8) and (9), we obtain the optimal second period prices as a function of q_E:

$$\widetilde{p}_{I,2} = \frac{3q_E^3 - 10q_E^2 + 4q_E + 3}{6(3q_E + 1)(q_E^2 - 2q_E - 1)}, \tag{13}$$

$$\widetilde{p}_E = \frac{6q_E^4 - 14q_E^3 - 4q_E^2 + 9q_E + 3}{6(3q_E + 1)(q_E^2 - 2q_E - 1)}. \tag{14}$$

[26] Again, this figure entails the equilibrium prices. In this case we use $q_E = 1.7$ because, as we will later show, this demand configuration is part of the equilibrium outcome only for high quality levels.

Later on we will make some comparative static analysis with respect to q_E. To conclude this description we can now insert the optimal prices in (10) and obtain the equilibrium number of consumers who do not buy in the first period as a function of entrant's quality:

$$\widetilde{t}_0 = \frac{4q_E^2 - 7q_E - 3}{6\left(q_E^2 - 2q_E - 1\right)}.$$

It is straightforward to show that, for every $q_E \in (1,2)$, the number of consumers who do not buy in the first period decreases with q_E, since:

$$\frac{dt_0}{dq_E} = -\frac{q_E^2 + 2q_E - 1}{6\left(q_E^2 - 2q_E - 1\right)^2} < 0.$$

This result seems counter intuitive because one could expect the number of first period buyers to decrease as entrant's quality increases, since entrant's product in the second period is more valuable for consumers if it has a higher quality. But, as we already mentioned, there are different trade-offs to consider. The higher that an entrant's quality is, the lower the incumbent's first period price: the incumbent must set a lower price in the monopoly period in order to be able to lock in consumers and this would decrease t_0. Furthermore, consumers anticipate that a higher entrant's quality implies a more aggressive competition in the next period. High quality implies higher utility, while higher prices (which come from higher quality) decrease utility. In this candidate equilibrium the first effect prevails and the number of first period purchasers increases with the entrant's quality.

Finally, note that in this candidate equilibrium the highest types among incumbent's attached consumers switch to the entrant in the second period.

3.3 Second Candidate Equilibrium

If the cut-off consumers are positioned in the following order (Case 2 in Appendix 1): $t_1 \geqslant 1 > t_0 > t_5 \geqslant 0$ and $t_2 \geqslant t_5$ then the demand functions we obtain are the following: $D_I(\cdot) = (1 - t_0)$, $D_{0,I}(\cdot) = 0$, $D_{I,I}(\cdot) = (1 - t_0)$, $D_{0,E}(\cdot) = (t_0 - t_5)$, $D_{I,E}(\cdot) = 0$. The difference with the previous demand configuration is that now all the new consumers buy in the second period from the entrant, and none of the incumbent's attached consumers switch in the second period: both firms specialize on a group of consumers.

In the second period the incumbent would have the incentive to continue raising its price in order to extract the maximal rent from the attached consumers. But there is a maximal second period price, which determines the demand configuration we are analyzing. The restriction which determines this upper bound for the second period incumbent's price is $t_2 \geqslant t_5$.[27] Since the incumbent gains the maximal profit if this inequality is satisfied as an equality, we determine $p_{I,2}$ from $t_2 = t_5$. We can now write the optimal second period prices as follows:

$$\tilde{\tilde{p}}_{I,2} = \frac{t_0}{2}, \tag{15}$$

$$\tilde{\tilde{p}}_E = \frac{t_0 \cdot q_E}{2}. \tag{16}$$

There are three interesting things to note. First, both firms set the monopoly price, since both have monopoly power over their customers. Second, the second period incumbent's price does not depend on the entrant's quality. This is because in this candidate equilibrium the incumbent does not compete for the new purchasers and only exploits its attached customers. Third, both prices increase with the number of consumers who don't buy in the first period. Switching costs do not directly enter the optimal second period prices, since in this candidate equilibrium none of the incumbent's attached consumers switch.

Also in this case the consumer t_0, indifferent between buying and not buying in the first period, compares $u_0^{t_0} + u_{0,E}^{t_0}$ and $u_I^{t_0} + u_{I,I}^{t_0}$ to take its first stage decision. Substituting (15) and (16) in the utility functions we can solve for $\tilde{\tilde{t}}_0$:

$$\tilde{\tilde{t}}_0 = \frac{2p_I}{3 - q_E}. \tag{17}$$

The number of consumers who do not buy in the first period increases with the first period incumbent's price, in fact $\frac{\partial \tilde{\tilde{t}}_0}{\partial p_I} = \frac{2}{3-q_E} > 0$ for every $q_E \in (1, 2)$.

We can now solve for the first period's optimal prices. In this case the level of switching costs is given as a lower boundary determined by the restrictions $(t_1 \geqslant 1)$, since switching costs do not enter the incumbent's profit.[28] We obtain:

$$\tilde{\tilde{p}}_I = \frac{3 - q_E}{4}, \tag{18}$$

[27] If this restriction would fail we would jump to another demand configuration, in which entrant and incumbent compete for new costumers. Actually this demand configuration would also lead to a candidate equilibrium. See the third case in Appendix 1.

[28] We determine s from $t_1 = 1$. But every value of $s > \tilde{\tilde{s}}$ could be part of the equilibrium outcome. However, the incumbent does not have the incentive to set an higher level of switching costs since $\tilde{\tilde{s}}$ is enough to lock in all the attached costumers.

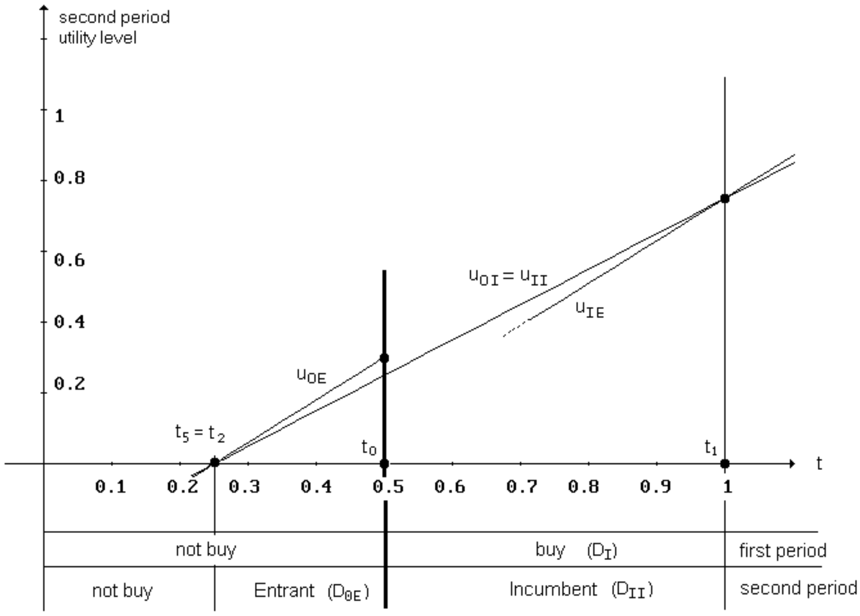

Figure 3: Second candidate equilibrium: demands ($q_E = 1.2$).

$$\tilde{\tilde{s}} = \frac{3\,(q_E - 1)}{4}. \tag{19}$$

Substituting these optimal prices and $\tilde{\tilde{t}}_0$ in (15) and (16) we get:

$$\tilde{\tilde{p}}_{I,2} = \frac{1}{4}, \tag{20}$$

$$\tilde{\tilde{p}}_E = \frac{q_E}{4}. \tag{21}$$

Substituting (18) in (17) we obtain $\tilde{\tilde{t}}_0 = \frac{1}{2}$, as in the benchmark case (see Figure 3).[29] This means that, independently of the entrant's quality level, half of the consumers buy from the incumbent in the first period.

In the following proposition we can show that the previous candidate equilibria actually define the unique subgame perfect equilibrium of the price setting game, depending on the entrant's quality level. We will determine a critical quality level which separates the two candidate equilibria. For

[29] In this case we use $q_E = 1.2$ because, as we will show later on, this is an equilibrium only for low quality levels.

values higher than this critical level, the equilibrium is defined by the first candidate equilibrium, whereas for lower values of the entrant's quality the equilibrium is defined by the second candidate. Recall, however, that the entrant's quality level will be endogenously chosen as a function of the cost of developing quality in the next section. We can then state the following proposition:

Proposition 1 *For every $q_E \in (1, \overline{q}_E)$, where $\overline{q}_E \approx 1.67785$, the price setting game presents a unique subgame perfect equilibrium outcome with entry given by (18), (19), (20), and (21). For every $q_E \in [\overline{q}_E, 2)$ the price setting game presents a unique subgame perfect equilibrium outcome with entry given by (11), (12), (13), and (14).*

Proof: The proof is in two steps. In a first step we show that the restrictions for the existence of the two candidate equilibria are satisfied by equilibrium prices. This part is presented in Appendix 2. In the second step we proof the uniqueness of the equilibrium as a function of the entrant's quality choice.

To determine the unique subgame perfect Nash equilibrium we must first solve all the other possible cases which are listed in Appendix 1. We do not report this step. We can find that only one other candidate equilibrium exists in the range $(\overline{\overline{q}}_E, 2)$ where $\overline{\overline{q}}_E \approx 1.7071$.[30] The incumbent has a first mover advantage in the price setting game. We assume that it chooses the equilibrium which generates the higher profit. We must then compare the reduced form incumbent's equilibrium profit functions for our three candidate equilibria. The three profit functions for the first, second, and third candidate equilibria are the following, respectively:

$$\widetilde{\pi}_I(q_E) = \frac{q_E\left(81q_E^5 - 288q_E^4 - 23q_E^3 + 468q_E^2 + 290q_E + 48\right)}{36\left(q_E^2 - 2q_E - 1\right)^2\left(3q_E + 1\right)}, \qquad \text{P1}$$

$$\widetilde{\widetilde{\pi}}_I(q_E) = \frac{4 - q_E}{8}, \qquad \text{P2}$$

$$\overline{\pi}_I(q_E) = \frac{\frac{1}{4}\left(32q_E^7 - 348q_E^6 + 1376q_E^5 - 2364q_E^4 + 1676q_E^3 - 515q_E^2 + 64q_E - 2\right)}{4\left(1 - 2q_E\right)\left(2q_E^2 - 7q_E + 2\right)}. \qquad \text{P3}$$

We plotted the three profits as a function of q_E in Figure 4. The in-

[30]This is Case 3 in Appendix 1. In this candidate equilibrium the position of the indifferent consumers is the following: $t_1 \geqslant 1 > t_0 > t_4 > t_2 \geqslant 0$. This implies that in the second period none of the attached consumers switch to the entrant, some of the new costumers buy from the entrant, and some from the incumbent.

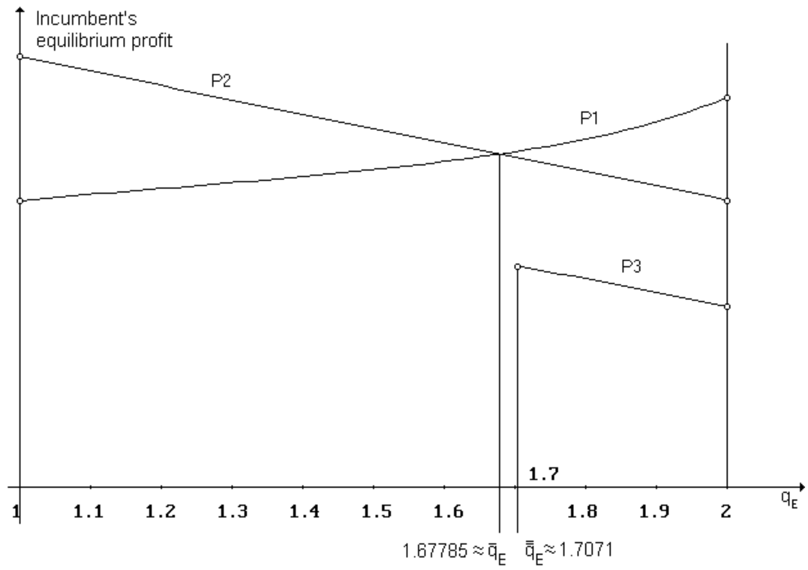

Figure 4: Incumbent's profits in the three candidate equilibria

cumbent chooses to play the equilibrium which generates the highest profit, given a particular entrant's quality level. Therefore the second candidate (which implies profit P2) is our unique subgame perfect equilibrium with entry for the price setting game in the first segment $(1, \overline{q}_E]$; and the first candidate (which implies profit P1) is our subgame perfect equilibrium with entry for the price setting game in the second segment $(\overline{q}_E, 2)$. We can also note that the third candidate equilibrium is, for the incumbent, always dominated. Therefore it can not be a subgame perfect equilibrium for the pricing game and hence for the entire game as well. ■

In the following section we can describe the main characteristics of the equilibrium making some comparative static analysis with respect to q_E.

3.4 Description of the equilibrium

We begin our description with the incumbent's first period choice. Because of switching costs the incumbent's trade off in the first period is in general between setting a high price in order to extract all monopoly rent, and setting a low price in order to attract consumers. In the benchmark case, incumbent's first period price is the monopoly price equal to 1/2 (the dotted line in Figure 5).

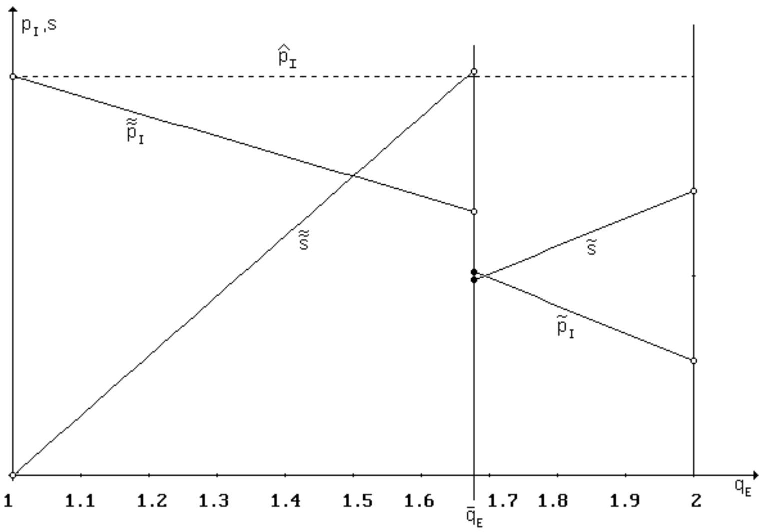

Figure 5: Incumbent's first period equilibrium price and switching costs.

In both scenarios of the equilibrium (or equilibrium segments) the second effect described above prevails, since the first period incumbent's price is lower with switching costs than in the benchmark case, independently of entrant's quality.[31] The higher that the entrant's quality is, the lower p_I. The incumbent's incentive to play aggressively in the first period is higher in the second equilibrium segment. This is because in this case the entrant has a stronger advantage over the incumbent, since the degree of product differentiation is higher. Therefore, the best strategy for the incumbent is to try to enlarge its customer base in the first period through low prices and increase its profit in the second through switching costs.[32]

Finally we can also note that in the first equilibrium segment the first period price (18) and switching costs (19) sum to $q_E/2$, while in the second (11) and (12) sum to $1/2$. However, one should also keep in mind that switching costs play different roles depending on the equilibrium segment: in the second segment they are a charge that attached consumers actually pay when switching, whereas in the first one they are only used to make switching too expensive.

[31] We will use the term equilibrium segment to indicate the prevailing scenario. If $q_E \in (\overline{q}_E, 2)$, for example, we will refer to it as the second equilibrium segment.

[32] This result was expected given the demand configuration. In the first candidate equilibrium more than $1/2$ of the consumers buy in the first period, while in the second exactly $1/2$ (independently of prices and entrant's quality) do it. Compare Figure 1 and Figure 2.

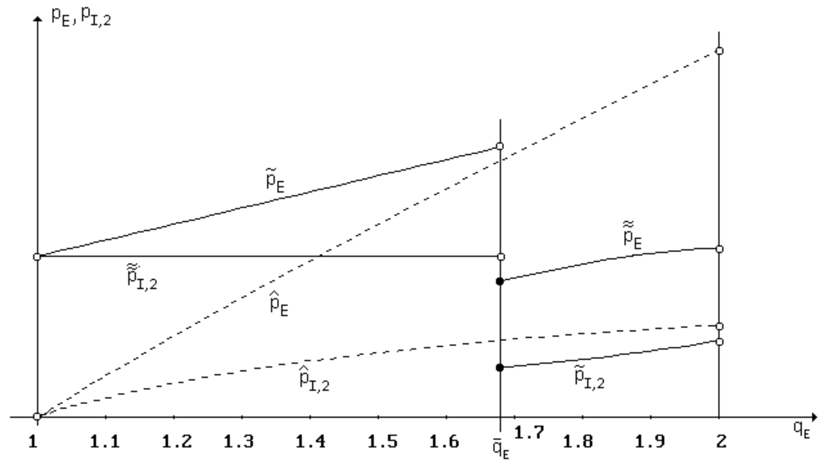

Figure 6: Incumbent's second period and Entrant's equilibrium prices.

Firms' second period behavior differs strongly in the two equilibrium segments as well (see Figure 6).[33] When products are not strongly differentiated both firms price less aggressively than without switching costs (dotted lines are benchmark prices), even though this effect declines the higher that the entrant's quality is. This behavior is easy to understand. In the second period both firms have monopoly power over their customers, and can price higher than in absence of switching costs.

When products become more differentiated (second equilibrium segment) competition becomes much tougher even in comparison to the benchmark case. Especially the entrant plays very aggressively in order to fully exploit the advantage coming from the high quality level of its product. In this case, prices are lower because the two firms compete for both groups of consumers. This result is particularly interesting. The typical finding of the product differentiation literature is that, the less that the products are differentiated, the more competitive the industry. We observe that in our model switching

[33]As TIROLE (1988) notes, if the incumbent firm can not discriminate between attached consumers and "new" purchasers, it will set an intermediate price which increases with the importance of the customer base. If one consider the customer base as a sort of investment, and if this base is large, it results that the incumbent firm is a "fat cat" which may make entry profitable. If the base is not large, then the prevailing strategy is a "top dog" strategy, where the incumbent firm plays aggressively. In our model both strategies are possible depending on the entrant's quality choice which determines the size of the customer base.

costs reverse this result, because of the lock in effect that they imply.

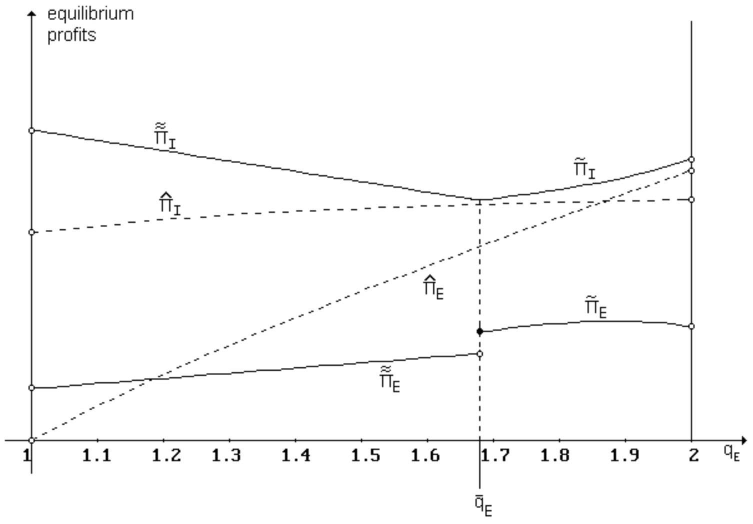

Figure 7: Firm's equilibrium profits $(c = 0)$

Finally, we can also stress the fact that the incumbent's profit function has not a monotonic behavior in entrant's quality (see Figure 7). The incumbent is always hurt by product differentiation in the first equilibrium segment. That is because it must lower the first period price in order to expand its customers base, but it can not increase the second period price as entrant's quality increases. Instead, in the second segment, the incumbent too gains from more differentiation, because of its increased profits via switching costs. The entrant always gains from differentiating its product in the first segment (its profit function net of costs monotonically increases in q_E), but this is not always the case in the second segment. In particular, at a certain point it may be not profitable to further increase quality given switching costs.[34] This fact also imply that in the switching cost equilibrium there is a maximal profitable level of product differentiation (for the minimum quality cost, $c = 0$), whereas in the benchmark case this would not be the case. In equilibrium the entrant is almost always worse off than in the benchmark case of no switching costs: the incumbent not only extracts part of the consumers' surplus but also some of the entrant's rent. Finally one should also note that even when products are not differentiated $(q_E \to 1)$ the entrant gains positive profits. This is

[34]The plotted entrant's profit is for the case of $c = 0$. The optimal entrant's quality is endogenously determined in stage 0 as a function of the cost to build up quality.

because the incumbent does not compete for the "new customers" and leaves the entrant with some extra rent (the "fat cat" strategy).

4 Entry Decision: The Endogenous Quality Choice

In this section we analyze the entrant's quality choice as a function of the cost parameter. In stage 0 the entrant chooses whether to invest in quality or not. Should it decide to set up a quality level this would mean that it wants to enter the market in period 2. We can use at this stage the result of the pricing game derived in the previous section. In this stage the entrant maximizes its reduced form profit function with respect to q_E. In the second equilibrium segment the first order condition gives implicitly entrant's optimal quality $(\widetilde{q}_E)$ as a function of the cost parameter c:

$$\begin{gathered}\frac{c\left[36\left(\widetilde{q}_E^2-2\widetilde{q}_E-1\right)^3(3\widetilde{q}_E+1)^3\right]}{(\widetilde{q}_E-2)}\\=\\(100\widetilde{q}_E^9-540\widetilde{q}_E^8+372\widetilde{q}_E^7+892\widetilde{q}_E^6+228\widetilde{q}_E^5)\\+\\(-82\widetilde{q}_E^4-1379\widetilde{q}_E^3-891\widetilde{q}_E^2-255\widetilde{q}_E-27)\end{gathered} \tag{22}$$

In the first equilibrium segment we are able to derive explicitly the optimal quality level as a function of c as follows:

$$\widetilde{\widetilde{q}}_E = 2 - 4\sqrt{2c}. \tag{23}$$

Proposition 2 *For every $0 < c < \overline{\overline{c}}$ (where $\overline{\overline{c}} \approx 0.0313$) high quality entry is accommodated. The optimal quality level is given by (23) if c is not too small ($\overline{\overline{c}} > c > \overline{c}$, $\overline{c} \approx 0.0059$). For very small values of c ($0 < c < \overline{c}$) the optimal quality level is implicitly given by (22).*

Proof We can use at this stage the result of Proposition 1. The entrant knows that the incumbent's best response to every quality in the range $(\overline{q}_E, 2)$ is to play according to the second equilibrium segment. In this segment the entrant maximizes its profits with respect to q_E and the optimal quality is given by (22). If $c = 0$ the optimal entrant's quality level is equal to $\widetilde{q}_E = 1.8836$. Furthermore the optimal entrant's quality decreases with c, since $\frac{\partial^2\widetilde{\pi}_E}{\partial\widetilde{q}_E\partial c} = -\frac{2}{(q_E-2)^2} < 0$ (see Figure 8). For $c = \overline{c}$ we obtain $\widetilde{q}_E = \overline{q}_E \approx 1.67785$. But if $q_E < \overline{q}_E$ the incumbent's best response to every entrant's quality is to play accordingly to the first

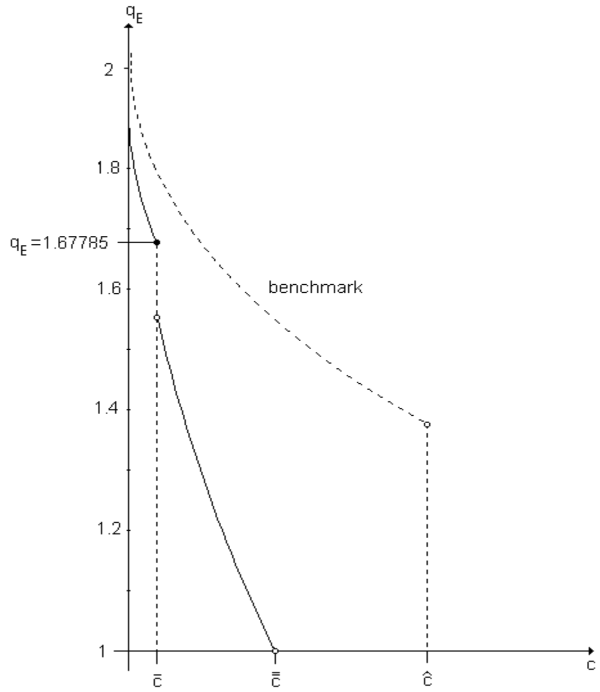

Figure 8: Entrant's equilibrium quality as a function of c.

equilibrium segment. The optimal entrant's quality is then given by (23), which is again a monotonic decreasing function of c in the relevant range. The minimum quality which we allow is 1, since we assume that the entrant is the high quality provider. If $\widetilde{\widetilde{q}}_E = 1$, then we obtain $c = \overline{\overline{c}} \approx 0.0313$, which implies positive entrant's profit. Therefore this is the maximal value of the cost parameter which allows *high quality* entry. ■

Now we know which is the entrant's optimal behavior in stage 0. From the previous proposition stems another interesting result.

Corollary 1 *In any switching costs equilibrium the entrant always underinvests in quality compared to the benchmark case.*

Proof Entrant's reduced form profit function in the benchmark case is given by:

$$\widehat{\pi}_E = \frac{4q_E (q_E - 1)}{(4q_E - 1)^2} - c \cdot \frac{q_E}{(2 - q_E)}$$

and the optimal quality level ($\widehat{q}_E$) is given implicitly by:

$$c\left(4\widehat{q}_E-1\right)^3=2\widehat{q}_E\left(\widehat{q}_E-2\right)^2\left(4\widehat{q}_E^2-3\widehat{q}_E+2\right).$$

Also in this case the optimal quality decreases with increasing costs ($\frac{\partial^2 \widehat{\pi}_E}{\partial \widehat{q}_E \partial c}=-2/\left(q_E-2\right)^2<0$). If $c=0$ we have $\widetilde{q}_E(c=0)=1.8836<\lim_{c\to 0}\widehat{q}_E=\infty$. If $c=\overline{\overline{c}}$ we obtain $\widetilde{q}_E(c=\overline{\overline{c}})=1.66786<\widehat{q}_E(c=\overline{\overline{c}})=1.79739$. We know that both functions are monotonically decreasing in c and that $\widehat{q}_E$ assumes higher value than $\widetilde{q}_E$ at the two extrema, therefore it has to assume a higher value in the entire range $0<c<\overline{\overline{c}}$ (see Figure 8). The same kind of proof can be done for the second cost segment ($\overline{\overline{c}}>c>\overline{c}$): both optimal quality functions decrease in c, and at the extrema $\widehat{q}_E>\widetilde{q}_E$ (see Figure 8). ■

In Proposition 2 we proved that, if the costs for product quality are not too high, entry is accommodated. The last point to clarify is how switching costs influence the entry behavior when product differentiation is very costly.

Proposition 3 *For every $\overline{\overline{c}}<c<\widehat{c}$ high quality entry is deterred by the strategic use of switching costs.*

Proof In Proposition 2 we have shown that in equilibrium entry happens for every $c<\overline{\overline{c}}$. In the benchmark case we can determine the cost parameter's value which implies zero entrant's profit. This value is $\widehat{c}\approx 0.0637$ which implies $\widehat{q}_E\approx 1.37688$. But $\overline{\overline{c}}<\widehat{c}$, therefore in equilibrium there is a smaller range of costs for which high quality entry happens than in the benchmark case (see Figure 8): high quality entry is deterred ■

This last finding is similar to the AGHION's and BOLTON's [1987] and KLEMPERER's [1987b] result. We can prove as well that switching costs can be used as an entry barrier, because they reduce the range of costs which allows the entrant to come into the market with a high quality product. But we can further show that they also lower the entrant's incentive to differentiate its product.[35] On the other hand we could also prove that, for some value of the quality dependent costs, switching costs may also lead to a more competitive industry, because they reduce prices. The next step consists in a more precise welfare analysis, which will allow us to make clearer policy suggestions.

[35]In a more general sense, if we consider that a higher degree of product differentiation needs a more innovative quality production process, we can conclude that switching costs slow the innovation process. This claim was used by the US Court of Justice as one of the motivations to declare Microsoft's *"per processor" licenses* illegal.

4.1 Welfare Analysis and Policy Suggestion

In this section we will analyze the welfare implication of the equilibrium outcome. We assume that the welfare function is the sum of consumers' surplus and firms' profits. In the previous Sections we observed that switching costs on the one hand can make the industry more competitive, but on the other reduce the entrant's incentive to differentiate and may deter entry. As we saw, the incumbent always gains from switching costs, whereas this is mostly not the case for the entrant (see Figure 7). The third party in the market are consumers. They gain higher utility from lower prices (in one equilibrium segment), but on the other side they may have disutility from the lower entrant's quality and from the lower "degree of entry" with respect to the case of no switching costs.[36]

Proposition 4 *The switching costs equilibrium outcome is always inefficient.*

Proof Consider the total welfare as a function of entrant's quality in the case of no quality costs (see Figure 9). One can see that in equilibrium the "net" total welfare is always lower than in the benchmark case of no switching costs .[37] But this must not necessary hold for the optimal quality. We can then recall Corollary 1 of the previous proposition. There we proved that for every $c \in \left(0, \overline{\overline{c}}\right)$ entrant's quality level is always lower in equilibrium than in the benchmark case. Thus, for $c \rightarrow 0$ total welfare in equilibrium must be lower than in the benchmark case. For $c \in (0, \overline{c})$ the equilibrium welfare function is given by:[38]

$$\widetilde{W}(c) = c\frac{\widetilde{q}_E}{\widetilde{q}_E - 2} + \frac{252\widetilde{q}_E^7 - 519\widetilde{q}_E^6 - 1186\widetilde{q}_E^5 + 1014\widetilde{q}_E^4 + 2584\widetilde{q}_E^3 + 1512\widetilde{q}_E^2 + 348\widetilde{q}_E + 27}{72\left(\widetilde{q}_E^2 - 2\widetilde{q}_E - 1\right)^2 (3\widetilde{q}_E + 1)^2}$$

and in the benchmark case the welfare function is the following:

$$\widehat{W}(c) = c\frac{\widehat{q}_E}{\widehat{q}_E - 2} - \frac{4\widehat{q}_E + 5}{32\,(4\widehat{q}_E - 1)^2} + \frac{3}{8}\widehat{q}_E + \frac{21}{32}$$

[36] This must not be true. In fact lower entrant's quality would imply lower prices, which increases consumers' surplus. The following welfare analysis should make clear which of the two effects prevails.

[37] "Net" total welfare means net of quality costs ($c = 0$).

[38] Note that $\widetilde{q}_E$ and $\widehat{q}_E$ are the optimal quality level in equilibrium and in the benchmark case respectively, and, as such, they are a function of c.

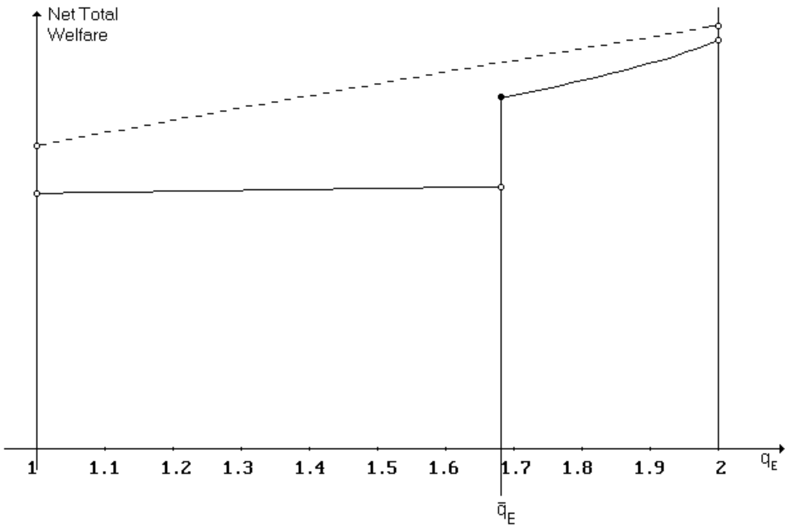

Figure 9: Total welfare ($c = 0$)

Both functions monotonically decrease as quality costs increase since for $q_E \in (1, 2)$ the following inequalities hold:

$$\frac{d\widetilde{W}(c)}{dc} = \underbrace{\frac{\partial \widetilde{W}(c)}{\partial c}}_{<0} + \underbrace{\frac{\partial \widetilde{W}(c)}{\partial \widetilde{q}_E}}_{>0} \underbrace{\frac{d\widetilde{q}_E}{dc}}_{<0} < 0,$$

and

$$\frac{d\widehat{W}(c)}{dc} = \underbrace{\frac{\partial \widehat{W}(c)}{\partial c}}_{<0} + \underbrace{\frac{\partial \widehat{W}(c)}{\partial \widehat{q}_E}}_{>0} \underbrace{\frac{d\widehat{q}_E}{dc}}_{<0} < 0.$$

In $c = \overline{c}$ it is $\widetilde{W}(c = \overline{c}) = 1.12540 < 1.26771 = \widehat{W}(c = \overline{c})$. But, if both functions monotonically decrease in c and at the extrema of the interval $(0, \overline{c}]$ it is $\widetilde{W}(c) < \widehat{W}(c)$, then this inequality must hold in the entire interval. Now consider the range of costs $c \in (\overline{c}, \overline{\overline{c}}]$. In this cost range the equilibrium welfare function is the following:[39]

$$\widetilde{\widetilde{W}}(c) = \frac{8c - 3\sqrt{2c} + 7}{8}$$

[39]In this case, since we could explicitly derive the optimal quality level, we can also explicitly write the welfare function as a function of c.

Also $\widetilde{\widetilde{W}}(c)$ is a decreasing function of the cost parameter.[40] For $c \to \overline{c}$ it is $\widetilde{W}(c) \to 0.84009 < 1.26771 = \widehat{W}(c)$. At $c = \overline{\overline{c}}$ we have $\widetilde{\widetilde{W}}(c = \overline{\overline{c}}) = 0.8125 < 1.11681 = \widehat{W}(c = \overline{\overline{c}})$. Therefore the same argument as before applies: both functions are monotonically decreasing in c in the relevant range of the cost parameter and at both extrema it is $\widetilde{\widetilde{W}}(c) < \widehat{W}(c)$, then the inequality must hold in the entire interval. ■

Through the strategic use of switching costs, the incumbent can extract some of the entrant's and some of the consumers' rent, expanding its market power also to the period of potential competition which implies losses for the economy.

Although the model we presented makes some strong simplifying assumptions, we think that it enables us to make some policy suggestions. The competition authority should be aware of the anticompetitive effects that the strategic use of switching costs by an incumbent may imply, and should try to avoid its use. In fact, even in the most positive of cases, when they may imply a more competitive industry in the sense of lower prices, they have also some negative implications in terms of a lower entrant's quality level, which would decrease total surplus. The negative effect of switching costs increases, the higher the cost of differentiation.

5 Conclusion

This paper deals with the analysis of the entry process in an ex-monopolistic industry, when the incumbent can lock in consumers *via* the strategic use of switching costs and the entrant can vertically differentiate its product. We showed that, depending on the investment costs of developing quality, three scenarios may emerge. If the entrant's investment costs are low, in equilibrium the industry is more competitive than in the benchmark case of no switching costs: the entrant differentiates strongly its product and firms set prices more aggressively than in the benchmark case. Switching costs imply that consumers distribution is split between incumbent's attached customers and new customers. In this case both firms compete in the second period for both types of consumers. The entrant, which is the high quality provider, attracts the "highest types" from both consumers' groups. If investment costs are in a middle range, the entrant can not strongly differentiate its product and both entrant and incumbent are less aggressive in the product market.

[40] In fact $\frac{d\widetilde{W}(c)}{dc} = \frac{\sqrt{2}\left(8\sqrt{2c}-3\right)}{16\sqrt{c}}$ is negative in the relevant range of the cost parameter.

Both firms price less aggressively because each of them has monopoly power over a group of consumers. The incumbent, in fact, does not compete for second period new customers and extracts rent from the attached ones. The entrant, instead, serve all the new buyers but none of the incumbent's attached customers. We can show that, due to switching costs and to the lock in effect which they imply, the more that the products are differentiated, the more competitive the industry, which is an atypical result for the literature on vertical product differentiation. For high differentiation costs, high quality entry is deterred. This is a similar result to AGHION and BOLTON [1987]. In our case, where costs are assumed to be observable, switching costs generate a barrier to entry because in equilibrium there is a smaller set of costs which allows the entrant to gain positive profits with a high quality product than in the benchmark case of no switching costs. Furthermore we could prove that the entrant always underinvests in quality with respect to the benchmark case, hence we always observe a lower degree of differentiation than we would do without switching costs. Finally we showed that the switching costs equilibrium is inefficient since total welfare is always lower with switching costs than without. In particular switching costs almost always reduce entrant's profits. The incumbent, instead, always gains from switching costs: they are a way of perpetuating its market power from the monopoly period to the period of potential competition. Consumers are almost always worse off in the switching costs equilibrium than in the benchmark case as well. Only for very low costs of differentiation do they enjoy some benefits, because of the more competitive environment and because the equilibrium entrant's quality is not much lower than without switching costs.

Although the model we presented makes some strong simplifying assumptions, we think it is able to shed light on some important aspects which were so far not analyzed in the literature, like the impact of switching costs on entrant's incentive to differentiate its product. This kind of analysis has also important implications for policy makers. Sometimes regulators have argued that switching costs slowed innovation, but this point wasn't theoretically clear. Our results partially help to clarify this claim.

The model can be extended in some directions. First, we did consider only the case of high quality entry, assuming that the entrant will always choose to be the high quality provider. We think that, for high quality dependent costs, probably one would observe low quality entry. But it could also be the case that for lower costs it would be more profitable for the entrant to be the low quality provider. Second, we did not allow the incumbent to react in the quality dimension. Although this extension could make the model more complete, we do not think that it would have very interesting implications, at least if one maintains the assumption of a high quality entrant. The incumbent, in fact, would have a further instrument to protect his dominant position, leading to a even less competitive and more inefficient outcome.

Appendix 1

In this Appendix we present all the possible demand configurations.

Cases	Position of the Cut-off Consumers	First Period	Second Period Incumbent	Second Period Entrant
1	$1 \geqslant t_1 > t_0 > t_4 > t_2 \geqslant 0$	$D_I(\cdot) = (1 - t_0)$	$D_{0,I}(\cdot) = (t_4 - t_2)$ $D_{I,I}(\cdot) = (t_1 - t_0)$	$D_{0,E}(\cdot) = (t_0 - t_4)$ $D_{I,E}(\cdot) = (1 - t_1)$
2	$t_1 \geqslant 1 > t_0 > t_5 \geqslant 0$ and $t_2 \geqslant t_5$	$D_I(\cdot) = (1 - t_0)$	$D_{0,I}(\cdot) = 0$ $D_{I,I}(\cdot) = (1 - t_0)$	$D_{0,E}(\cdot) = (t_0 - t_5)$ $D_{I,E}(\cdot) = 0$
3	$t_1 \geqslant 1 > t_0 > t_4 > t_2 \geqslant 0$	$D_I(\cdot) = (1 - t_0)$	$D_{0,I}(\cdot) = (t_4 - t_2)$ $D_{I,I}(\cdot) = (1 - t_0)$	$D_{0,E}(\cdot) = (t_0 - t_4)$ $D_{I,E}(\cdot) = 0$
4	$1 \geqslant t_0 \geqslant t_1 > t_4 > t_2 \geqslant 0$	$D_I(\cdot) = (1 - t_0)$	$D_{0,I}(\cdot) = (t_4 - t_2)$ $D_{I,I}(\cdot) = 0$	$D_{0,E}(\cdot) = (t_0 - t_4)$ $D_{I,E}(\cdot) = (1 - t_0)$
5	$1 \geqslant t_1 > t_0 > t_5 \geqslant 0$ and $t_2 \geqslant t_5$	$D_I(\cdot) = (1 - t_0)$	$D_{0,I}(\cdot) = 0$ $D_{I,I}(\cdot) = (t_1 - t_0)$	$D_{0,E}(\cdot) = (t_0 - t_5)$ $D_{I,E}(\cdot) = (1 - t_1)$
6	$1 > t_0 \geqslant t_1 > t_5$ and $t_2 \geqslant t_5$	$D_I(\cdot) = (1 - t_0)$	$D_{0,I}(\cdot) = 0$ $D_{I,I}(\cdot) = 0$	$D_{0,E}(\cdot) = (t_0 - t_5)$ $D_{I,E}(\cdot) = (1 - t_0)$
7	$1 \geqslant t_1 > t_4 \geqslant t_0 > t_2 \geqslant 0$	$D_I(\cdot) = (1 - t_0)$	$D_{0,I}(\cdot) = (t_0 - t_2)$ $D_{I,I}(\cdot) = (t_1 - t_0)$	$D_{0,E}(\cdot) = 0$ $D_{I,E}(\cdot) = (1 - t_1)$
8	$1 \geqslant t_1 = t_4 = t_0 > t_2 \geqslant 0$	$D_I(\cdot) = (1 - t_0)$	$D_{0,I}(\cdot) = (t_0 - t_2)$ $D_{I,I}(\cdot) = 0$	$D_{0,E}(\cdot) = 0$ $D_{I,E}(\cdot) = (1 - t_0)$
9	$t_1 \geqslant 1 > t_4 \geqslant t_0 > t_2 \geqslant$	$D_I(\cdot) = (1 - t_0)$	$D_{0,I}(\cdot) = (t_0 - t_2)$ $D_{I,I}(\cdot) = (1 - t_0)$	$D_{0,E}(\cdot) = 0$ $D_{I,E}(\cdot) = 0$

Appendix 2

In this Appendix we present part of the proof of Proposition 1.

Step 1: verification of the restrictions.

In the following we report the 5 restrictions we imposed to determine demand for the first candidate equilibrium.

$$1 \geqslant t_0 \Longrightarrow \frac{1}{3} - \frac{1}{6\left(q_E^2 - 2q_E - 1\right)} \geqslant 0, \qquad \text{A1}$$

$$t_1 > t_0 \Longrightarrow -\frac{q_E}{6\left(q_E^2 - 2q_E - 1\right)} > 0, \qquad \text{A2}$$

$$t_0 > t_4 \Longrightarrow \frac{6q_E^3 - 6q_E^2 - 11q_E - 3}{6\left(q_E^2 - 2q_E - 1\right)\left(3q_E + 1\right)} > 0, \qquad \text{A3}$$

$$t_4 > t_2 \Longrightarrow \frac{3q_E^3 - q_E^2 - 9q_E - 3}{6\left(q_E^2 - 2q_E - 1\right)\left(3q_E + 1\right)} > 0, \qquad \text{A4}$$

$$t_2 \geqslant 0 \Longrightarrow \frac{3q_E^3 - 10q_E^2 + 4q_E + 3}{6\left(q_E^2 - 2q_E - 1\right)\left(3q_E + 1\right)} \geqslant 0. \qquad \text{A5}$$

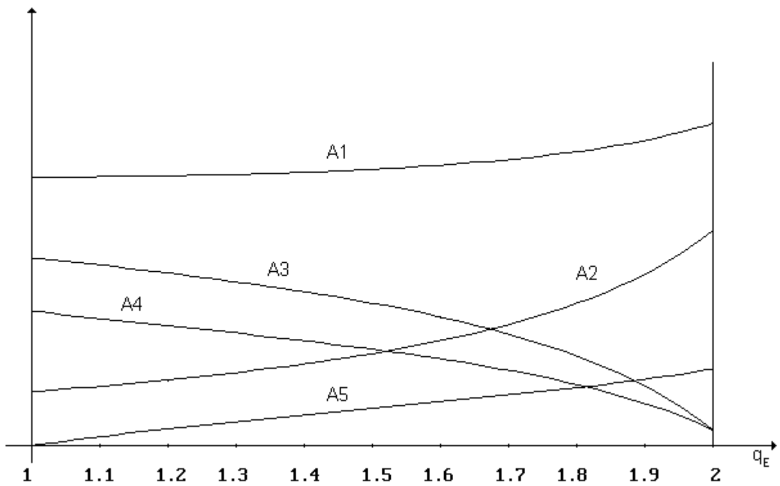

Figure 10: Restrictions for the first candidate equilibrium

They are all satisfied in the relevant range of entrant's quality (see Figure 10). We can therefore conclude that this is a candidate subgame perfect equilibrium for the pricing game in the entire range of entrant's quality.

In the second candidate equilibrium the restrictions to verify are the following: $1 > t_0 > t_5 \geqslant 0$.[41] In this candidate equilibrium $t_0 = 1/2 < 1$, the first restriction is then satisfied. It is also true that, for every $q_E \in (1, 2)$, it holds $t_5 = 1/4 > 0$. We must then only verify $t_0 > t_5$. But substituting the optimal prices (18), (20), and (21) in t_0 and t_5 we obtain $-1/4 < 0$ which is always true. This is a candidate equilibrium defined in the range $q_E \in (1, 2)$.

[41] The two other restrictions ($t_1 \geqslant 1$ and $t_2 \geqslant t_5$) are of course satisfied since we used them to derive the equilibrium outcome.

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